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LIFE CYCLE COSTING IN
SPARE PARTS PROCUREMENT:
A DECISION MODEL

by

Ruth Graham

June 1988

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Life Cycle Costing in Spare Parts Procurement: A Decision Model

by

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ABSTRACT

Life cycle costing methods can be applied to the procurement of some, but not all, spare parts. As a result, a decision model is needed to determine which spare parts should be considered for life cycle costing. This thesis discusses a decision model for determining the applicability of life cycle costing to spare parts procurement. The thesis briefly reviews the application of the life cycle cost concept to the acquisition of major systems and associated spare parts. It then reviews current spare parts acquisition techniques and identifies critical criteria to be considered during the acquisition of spare parts using life cycle costing techniques. Finally, the thesis uses the identified characteristics to develop the decision model.

TABLE OF CONTENTS

I. INTRODUCTION

A. AREA OF RESEARCH

The researcher is convinced that some spare parts lend themselves to life cycle costing (LCC). Applying life cycle costing methods to these parts will reduce operating and support costs of the system in which the parts are installed; will reduce the amount of maintenance required on these systems; and will increase the availability of that system. This thesis will seek to develop a decision model for identifying spare parts which lend themselves to procurement using life cycle costing methods. In support of this effort life cycle costing and spare parts procurement methods will be reviewed, various characteristics of spare parts will be identified, hierarchical relationship between these characteristics will be determined, the qualitative decision model will be developed using these characteristics, and, finally, the decision model will be described.

B. RESEARCH QUESTIONS

The principal research question for this study is: What decision process should be used to determine application of life cycle costing to spare parts?

Subsidiary research questions include:

1. What are life cycle costs?

2. How are life cycle costing methods applied to major system acquisitions?

3. What are spare parts?

4. What are the principal characteristics of spare parts?

5. What spare part characteristics are significant to determining the applicability of life cycle costing methods to spare part procurement and how should they be considered in determining the applicability of life cycle costing?

6. What are the key elements of a decision model which could be used to identify candidate spare parts for life cycle costing and how should the model be applied?

C. DISCUSSION

Life cycle costs are generally defined as:

> The sum total of the direct, indirect, recurring, non-recurring, and other related costs incurred, or estimated to be incurred in the design, research and development (R&D), investment, operation, maintenance, and support of a product over its life cycle, i.e., its anticipated useful life span. It is the total cost of the R&D, investment, O&S and, where applicable, disposal phases of the life cycle. All relevant costs should be included regardless of funding source or management control. [Ref. 1:p. 13]

For the purpose of this thesis, life cycle costs, when dealing with spare parts, are defined as total costs over the effective life of the spare part. The effective life is the period from installation into a system to disposal. The effectiveness of life cycle costing can be measured in terms of cost per some level of performance. [Ref. 2:p. 39] The purchase of aircraft tires in terms of dollars per landing versus lowest purchase price per tire is an example of the application of life cycle costing methods to spare parts procurement.

For the purpose of this thesis, spare parts will be defined as:

> Spares and repair parts, repairable and consumable, purchased for use in the maintenance, overhaul, and repair of equipment such as ships, tanks, guns, aircraft, missiles, ground communication and electronic systems, ground support and associated test equipment. ...it includes items, spares, repair parts, parts, subassemblies, components, and subsystems, but excludes end items such as aircraft, ships, tanks, guns and missiles. [Ref. 3:p. 5]

The Department of Defense (DOD) procurement process is under increasing scrutiny in this time of rising costs. As a result, DOD has adopted an affordability acquisition policy. An affordability acquisition policy is one that forces programs manager to consider operating and support costs in addition to the acquisition cost. DOD must be able to afford to operate the system once it is fielded. [Ref. 1:p. 15] Affordable materials in terms of "both initial cost and support cost becomes more critical as the present budget trends continue." [Ref. 4:p. 1] Long states that:

> The LCC concept was introduced in the early 1960s primarily because of increasing concern over the consequences of competitive procurement without regard to total lifetime cost of a weapon system. Today, LCC is a major part of the DOD management strategy to control the increasing cost of defense systems. [Ref. 4:p. 1]

Reinhardt found that items with the lowest purchase price tended to have a higher life cycle cost. Conversely, when using life cycle cost procurement methods, the item with the lowest life cycle cost tended to be selected instead of the item with the lowest purchase price. [Ref. 5:p. 1] The important issue here is that, in this time of constrained

budgets, it is often difficult for the DOD manager to be concerned with future savings in the system's or item's operation and support phase, when current procurement dollars are limited. To meet current budget constraints, the tendency exists to look to the short term and buy based on the lowest purchase price. Long's study noted:

> Prior to the inception of LCC, the federal government customarily sought to buy the least expensive product available. Contracts normally were awarded to the lowest bidder. Although there were exceptions, this practice resulted in the acquisition of many weapon systems that were expensive and difficult to maintain. [Ref. 4:p. 2]

To avoid these problems, life cycle costing methods have been developed and have been applied to major system acquisitions.

Life cycle costing methods will result in lower lifetime costs for the systems to which they are applied. Can life cycle costing methods be applied to spare parts procurement? What factors must be considered to determine if life cycle costing methods are applicable to specific spare parts? Which brings us to the principal research question of this thesis: "What decision process should be used to determine application of life cycle costing to spare parts?"

D. SCOPE OF THE THESIS

This thesis is directed towards management level personnel and is not intended to provide a quantitative model for use in applying life cycle costing methods to spare parts procurement. Further, it is not intended to be a detailed discussion of the procedures used to accumulate life cycle

cost data or of the analytical techniques used in evaluating these data. The goal is to provide management with a tool to identify spare parts to which to apply life cycle costing techniques.

E. ASSUMPTIONS

In this thesis it was assumed that the reader has a working knowledge of:

1. DOD life cycle costing policies and procedures.

2. DOD contracting policies and procedures.

3. DOD major system acquisition policies, procedures and phases.

3. DOD spare parts requirements determination policies and procedures.

4. DOD provisioning and replenishment policies and procedures.

F. LIMITATIONS

Specifically excluded from this study are:

1. A detailed discussion of the methods used to estimate life cycle costs.

2. A detailed discussion of current methods for procuring spare parts.

3. A detailed discussion of techniques used by the Government in applying life cycle costing methods.

4. A detailed discussion of the accounting system used to accumulate data for life cycle cost estimation.

5. A detailed discussion of LCC models or their application.

G. METHODOLOGY

The primary method of research to support this study was a literature search using the Defense Logistics Studies Information Exchange, the Defense Technical Information Center and the National Technical Information Service.

The objective of the literature review was to identify as many characteristics of spare parts as possible, to review other decision models, and identify their strengths and weaknesses. In addition the literature review identifies issues and concerns associated with the decision models currently used for DOD wide application.

H. ORGANIZATION

This thesis consists of the introductory chapter, and chapters on: life cycle costing, spare parts procurement, development of the decision model, demonstration of the decision model, and conclusions and recommendations.

Chapter II contains a general discussion of life cycle costing including a historical perspective on life cycle costing and why it is important. This chapter answers the questions: "What are life cycle costs?" and "How are life cycle costing methods applied to major systems acquisition?".

Chapter III contains a general discussion of spare parts procurement. It briefly discusses the provisioning and replenishment process. The chapter concludes with a discussion of the major characteristics of spare parts. This

chapter answers the questions: "What are spare parts?" and "What are the principal characteristics of spare parts?".

Chapter IV develops a decision model to be used in determining whether or not a specific spare part should have life cycle costing procedures applied to it. This chapter answers the questions: "What spare part characteristics are significant to determining the applicability of life cycle costing methods to spare part procurement and how should they be considered in determining the applicability of life cycle costing?" and "What are the key elements of a decision model which could be used to identify candidate spare parts for life cycle costing and how should the model be applied?" This chapter also provides the mechanism for answering the principal research question: "What decision process should be used to determine application of life cycle costing to spare parts?"

Chapter V is a demonstration chapter. It provides two examples of the application of the decision model developed in Chapter IV.

Finally, Chapter VI combines and summarizes the results of Chapters III through V to answer the principal research question.

I. SUMMARY

This thesis provides item managers and contracting officers with a simple mechanism for determining if life cycle costing methods should be applied to some specific

spare part. It will also provide general information on life cycle costing methods and their uses; and on spare parts, their procurement and their characteristics. This thesis now continues with a discussion of life cycle cost.

II. LIFE CYCLE COST: A REVIEW

Life cycle cost refers to both the acquisition cost and the cost of ownership. This concept is now well entrenched in the military's major systems acquisition process. The purpose of this chapter is to familiarize the reader with the history of the life cycle cost concept, its objective, use, and methodology.

A. BACKGROUND

During the 1940's and early 1950's, management effort within DOD was focused on manufacturing techniques and production rates, but not on cost. Each service followed its own acquisition strategy, initiating as many new programs as the current budget would permit. The services would then use these new programs as justification for increasing their share of future budgets. The problem with this approach was that these new programs were entered into at low cost during the initial stages of development, but could not be continued in subsequent years due to substantial cost increases in later phases. [Ref. 6:p. D-2]

The primary cost reduction techniques during this period and the early 1960's was the "meat axe" approach. This approach either canceled programs outright or stretched them out to reduce the annual impact of the program's cost. [Ref.

6:p. D-4] The problem here was that dollars were wasted on programs that were discontinued or stretched out.

Although cost received more attention during the early 1960's, it still wasn't on an equal footing with performance requirements and schedule considerations. Instead, more and more emphasis was placed on improving the engineering and system development process to prevent "costly problems and improve overall program's development efficiency and effectiveness". [Ref. 6:p. D-4]

Then during the late 1960's, DOD took control of the major system acquisition process away from the individual services. Under the resulting centralized guidance, the acquisition process included milestones and decision papers. As a result, there was a greater emphasis on cost estimates and trade-offs. These trade-offs were between reliability, cost and performance. This new emphasis on cost estimates and trade-offs profoundly affected the system's life cycle cost although the "life cycle cost concept" was not yet fully developed. [Ref. 6:p. D-5]

Finally, in 1971, with the issuance of DOD Directive 5000.1, life cycle cost analysis became firmly established as a requirement for the acquisition of major weapon systems. [Ref. 7:p. 4]

B. OBJECTIVE OF LIFE CYCLE COSTING

"The objective of introducing LCC was to engender an integrated systems analysis and economic feasibility approach

to defense systems acquisition processes." [Ref. 7:p. 3] The intent is to influence system design to minimize total system cost over the life of the system. [Ref 8:p. 1] What this means is that the life cycle cost concept forces the program manager to consider not only the performance level and schedule constraints of the system, but also the financial consequences of decisions made with regards to the design of the system. The requirement to review the life cycle cost of the system ensures at least the recognition of future costs associated with the system. These future costs are the deployment costs, the operating and recurring support costs, and the disposal costs. [Ref. 1:p. 20]

From 1972 to 1980, the Navy's annual budget didn't grow. To compensate, investment in new weapon systems declined by two percent while operations and maintenance appropriations increased by four percent. During the years since 1980, investment in new systems has increased significantly, yet budget restraints have continued. [Ref. 9:p. 43] In today's environment of further belt tightening in light of the Gramm-Rudman-Hollings act, it has become increasingly more critical that both the cost of acquisition and the cost of operation and support be controlled.

Life cycle costing is a management tool that can be used not only to evaluate the system to be acquired, but to evaluate alternative designs of the system to choose the most cost effective. As a tool, life cycle cost can also be used to

evaluate decisions at the various milestones of the acquisition process to identify the effect of the alternative decisions on the life cycle cost of the system. Additionally, if life cycle cost is identified in the Request for Proposal (RFP) for the system being procured as a selection criterion, then it also serves as a tool to select a source of supply. [Ref. 10:p. 1]

C. THE IMPORTANCE OF LIFE CYCLE COSTING

Life cycle costing is so important because DOD managers are entrusted with public funds and must, therefore, be able to justify current expenditures and later requirements for funding. Additionally, current budgetary constraints require that the DOD manager be able to justify the need for a new system. The researcher believes that, in addition to increasing the combat effectiveness of our military forces, an excellent justification for a new system is that the new system will be cheaper to operate and will, therefore, save money later. Finally, the manager must be aware of possible future budgetary constraints and recognize that any system procured today must be affordable in the future.

In light of the current political environment, which has great concerns over deficit spending, DOD will probably have to support more planes, ships, tanks, and other weapon systems with the same or a smaller budget. To accomplish this, each dollar must be spent more efficiently. DOD must

acquire the best possible product at the lowest possible life cycle cost.

Since DOD must try to be more efficient, it would not be realistic to only consider the purchase price of a new weapon system because all systems, once deployed, must be operated and supported. Operations and maintenance funds are just as tight as procurement funds.

In addition to being inefficient, buying a weapon system solely on the basis of purchase price can also be a dangerous proposition. One researcher stated: "There are few things that can't be made a little worse and a little cheaper." [Ref. 11:p. 29] So DOD could buy systems cheaply now, but pay the price later in the form of higher operating and support costs.

NAVSUP Instruction 4000.32 [Ref. 12] states:

> The costs to operate, maintain and support most equipments or systems over their life cycle are generally far greater than the initial investment. Therefore, each of the total spectrum of identifiable costs to support and to maintain equipments should be separately evaluated and traded off against all other identifiable cost to determine the most cost-effective combination of the major identifiable factors...

To avoid excessively high operating and support costs in the future, the DOD manager should consider the total life cycle cost of the weapon system under consideration before acquisition. The consideration of the total life cycle cost is important because DOD dollars are presently constrained and will probably continue to be constrained, therefore, the

DOD manager must consider the future affordability of the system.

D. LIFE CYCLE COSTING OF MAJOR SYSTEMS

Chapter I provided a lengthy definition of life cycle costs. A more concise definition is that life cycle costs consist of the system's acquisition cost, its operating and support cost and its disposal cost.

The acquisition cost is comprised of research, development, production, and construction costs plus contractor's profit. Research and development costs are composed of:

> ...the cost of feasibility studies; system analysis; detail design and development, fabrication, assembly, and test of engineering models; initial system test and evaluation; and associated documentation. [Ref. 8:p. 3]

Production and construction costs consist of:

> ...the cost of fabrication, assembly and test of operational systems (production models); operation and maintenance of the production capability; and associated <u>initial</u> logistic support requirements (e.g., test and support equipment development, spare/repair parts provisioning, technical data development, training, entry of items into the inventory, facility construction, etc.). [Ref. 8:p. 3]

The second element of life cycle costs are the operating and support costs.

> Operating costs are incurred during the use of an item (personnel, fuel, and operating support), and support costs are those for maintenance, provisioning, support equipment, training, technical manuals, and other nonoperating support functions (site preparation, and installation and security requirements). [Ref. 13:p. 67]

Finally, disposal costs refer to the costs associated with taking a system out of service. This can include the

cost of destruction, disassembly, transportation to the disposal site, and special handling for hazardous materials. "For most weapon systems, disposal costs are small, compared to other costs." [Ref. 13:p. 111] The exceptions occur when dealing with systems that have been in contact with hazardous materials (e.g., explosives, propellants, carcinogens, nuclear materials, nuclear wastes).

Of these life cycle costs components, operating and support costs are the largest. These operating and support costs have been estimated to be as much as 10 times greater than acquisition costs. [Ref. 1:p. 18]

In light of the magnitude of the operating and support costs, the DOD manager should not ignore these costs when acquiring new systems. As systems become more complex and thus probably more expensive to maintain, it becomes evident that the total life cycle costs of the system must be considered when acquiring a system, so that DOD will be able to afford the system once it is fielded.

E. LIFE CYCLE COSTING OF SPARE PARTS

As stated in Chapter I, when dealing with spare parts, life cycle costs are defined as the total cost of the part over its effective life. The effective life refers to the period of time from installation into a weapon system or piece of equipment to the disposal of that part. It is measured in terms of cost per some level of performance. [Ref. 2:p. 39]

The above definition of life cycle costs when addressing spare parts was obtained from Markowitz' 1971 study entitled Life Cycle Costing Applied to the Procurement of Aircraft Spare Parts [Ref. 2]. The literature review yielded only this one study dealing specifically with the application of life cycle costing techniques to spare parts procurement. Another study was performed by Reinhardt and Leggett in 1977 and, although its purpose was not to specifically address life cycle costing for spare parts, it did briefly discuss life cycle costing for consumables such as aircraft tires and batteries. This latter study was entitled The State of the Art of Life Cycle Costing [Ref. 5].

When measuring the effectiveness of life cycle costing of spare part in terms of cost per some level of performance, Reinhardt recommends that these performance levels be determined through laboratory testing, although historical data, if appropriate records are available, can be used. Reinhardt makes this recommendation because DOD has better control over a laboratory environment. Performance levels obtained from the field depend on the skill of the operator of the system containing the part, performance of preventative maintenance on the system containing the part, record keeping on the performance of the part by the field operators, and the accuracy and completeness of field maintenance records. Laboratory values for performance measures will eliminate much uncertainty regarding accuracy of the values and provide

a controlled environment in which parts are tested. This will ensure that all candidate spare parts being considered for procurement using life cycle costing methods are fairly and equitably evaluated. [Ref. 5:p. 12]

Reinhardt recommends the use of failure rates as measures of the performance levels because high failure rates result in greater maintenance and repair costs. These higher maintenance and repair costs translate to higher operating and support costs. As a result, the life cycle cost of spare parts with higher failure rates would be higher. [Ref. 5:p. 12]

To apply life cycle costing to spare parts, at least one performance measure must be defined. The life cycle cost will still include acquisition cost, operating and support costs and disposal cost, only the measure will differ from that used for major systems. Instead of defining the life cycle cost strictly in terms of total dollars, it will be expressed in terms of cost per some level of performance. The goal is to minimize the cost per level of performance and thereby minimizing the total life cycle cost of the spare part. [Ref. 2:p. 39]

The acquisition cost when dealing with spare parts consists only of the production costs. The researcher believes that, since spare parts are in fact duplicates or replacements for existing items, research and development costs are sunk costs. When dealing with life cycle cost of a

spare part, the concern should be for improvements over current cost per level of performance. The interest is, therefore, in the incremental difference in the life cycle costs of the alternatives. Sunk costs and other cost elements not affected should not be considered. [Ref. 11:p. 28]

The operating and support costs of a spare part are the inventory costs, the transportation costs, the costs of failure of the item, the costs of installing and removing the item, and other similar costs.

The disposal costs for a spare part are defined in the same way as for a major system. Disposal costs for spare parts should be relatively small unless special handling and disposal procedures are necessary.

F. APPLICABILITY OF LIFE CYCLE COSTING

Life cycle costing of both spare parts and major weapon systems is most effective when applied to situations where operating costs are high relative to the purchase price.

> The consequence of this logic is that LCC will tend to be applied to items that have a large input of consumables, are complicated and require maintenance, or which require a substantial amount of management. [Ref. 5:p. 4]

High operating cost does not mean that life cycle costing techniques are only applied to complex items. They can be applied to simple, non-repairable items to reduce the frequency of replacement, such as aircraft tires or other spares. [Ref. 5:p. 4]

The size of the procurement must be large. This is necessary because a large dollar value procurement is required so that marginal improvements in life cycle cost will exceed the additional cost of administering the life cycle cost procurement. [Ref. 5:p. 4]

The elements (i.e., performance measures) to be used in the life cycle costing process should be in quantitative form to avoid confusion over performance requirements of the system or item being acquired. This is especially important to ensure that solicitations provide for fair competition among offerors. [Ref. 5:p. 5]

Finally, to define these performance measures quantitatively, reliable data are required on the item or system being procured. These data must be accurate, current and properly applied. [Ref. 5:p. 6]

G. USES OF LIFE CYCLE COSTING

The life cycle cost concept can be used as follows [Ref. 13:p. 11]:

1. To evaluate alternative programs or items with respect to total life time cost, so that the manager can determine the most cost effective way of spending limited dollars.
2. To identify and justify future budgetary needs.
3. To compare alternative logistic support approaches on the basis of the total cost of each proposal.
4. To determine the cost efficiency of replacing aging equipment. It can aid in determining whether or not it will be cheaper, in the long run, to invest in the new equipment.

5. To evaluate alternative decisions that arise at various points in time during the system acquisition process.

6. To select contractors to develop and produce major systems on the basis of life cycle cost.

Life cycle cost analysis can also be used to identify those costs of a system that can be influenced by planning and design decisions. It can be used as a mechanism for evaluating trade-offs between performance, schedule and cost (within established constraints). Also, aside from being used to select a contractor, it can be used as a measure of the contractor's performance. Through rigorous testing it can be determined whether or not the contractor's product lives up to the life cycle requirements or the contractor's claims. [Ref. 1:p. 17]

H. METHODOLOGY

The following methodology is intended to be a general guideline for life cycle cost analysis. It must be tailored to a specific system or item acquisition to be effective. [Ref. 7:p. 20]

1. State the Objective

This step defines the scope of the analysis, the cost estimating methods to be employed and the sources and type of data to be used. This phase also identifies the schedule for the life cycle cost analysis, the resources required for applying life cycle costing methods and limitations on those resources. [Ref. 7:p. 21]

2. Define Assumptions

To make life cycle cost models more realistic, values for certain parameters may have to be assumed because all data may not available. Assumptions are made concerning such items as future interest rates, discount rates, and the length of the life of the system. [Ref. 7:p. 23]

3. Develop Cost Breakdown Structure

> A cost breakdown structure (CBS) is a hierarchical and logical subdivision of cost by functional activity area, major elements of a system, system components and for one or more discrete classes of items. [Ref. 7:p. 23]

This breakdown must be carefully chosen, giving consideration to available data and requirements of the cost model. [Ref. 7:p. 23]

4. Select a Cost Estimation Tool

Various cost estimation tools are available. These include analogy, parametric and engineering methods. Analogy is the least precise estimating tool and is applied very early in the acquisition cycle (i.e., the demonstration and validation phase of a major system) when little or no historical data are available on the system for which cost estimates are being developed. It is a process by which the estimator infers costs for an item or system based on the actual historical costs of a similar item or system. These historical costs are adjusted for such differences as technology, inflation and configuration. [Ref. 1:p. 21]

Parametric estimating methods use cost estimating relationships to determine the cost of a system. These cost

estimating relationships are mathematical relationships between some variable characteristic (such as actual failure rates) and the cost of the system or item. Actual historical data must be available on the system in order to apply this estimating method, therefore, the system should be in the latter stages of full scale development. [Ref. 1:p. 22]

Engineering estimating methods involve a bottoms up approach to determine detailed costs. This is the most complex method of estimating and like parametric estimating should not be applied until the full scale development phase of the major system's acquisition. [Ref. 1:p. 23]

> The degree of product refinement determines the applicability of each technique. In general, analogy and parametric are most useful during the early stages of a product's life, serving as an order-of-magnitude estimate of the potential costs. As the design stabilizes and more information becomes available, parametric cost estimating becomes a more useful technique. Later, when the detailed product design has occurred and specific tasking requirements can be levied, engineering estimates and the projection of actuals may become a more appropriate device for estimating cost. [Ref. 1:p. 21]

5. Collect the Data

This effort can be very difficult, because often the data are not readily available. Data which are not available must be estimated, and the estimate must then be updated as data become available. For the sake of accuracy, the analyst must use the most current data available. [Ref. 7:p. 24]

6. Generate the Life Cycle Cost Estimate

Given the cost breakdown structure, estimating methods, data collected, and the life cycle cost model

selected, the analyst can now estimate the life cycle cost of the system. [Ref. 8:p. 24]

7. Perform the Sensitivity Analysis

Although they can't be eliminated, the problems of uncertainty and risk in life cycle costing can be identified and reduced. This can be done through risk and sensitivity analysis. "Risk analysis is a procedure for analyzing how randomness affects the total cost." [Ref. 4:p. 12] Regarding sensitivity analysis the author goes on to say:

> ...sensitivity analysis is designed to systematically explore the implications of varying assumptions about the future environment and is normally centered on the cost drivers where a range of alternative parameters is investigated. [Ref. 4:p. 13]

8. Document the Analysis

The seven steps described above should be documented so that a written record exists of the analysis and its results. [Ref. 7:p. 25] See Figure 1 on the following page for a summary of these eight steps.

I. REQUIREMENTS FOR SUCCESS

To state that life cycle costing has attained full acceptance and enthusiastic support within DOD would be an exaggeration. The advantages of spending additional dollars early in the acquisition process to reap much greater benefits during later phases is clear. [Ref. 13:p. 4] However, the tendency exists to continue doing business as usual, i.e., to buy on the basis of lowest purchase price unless required to do otherwise. To expand the use of life

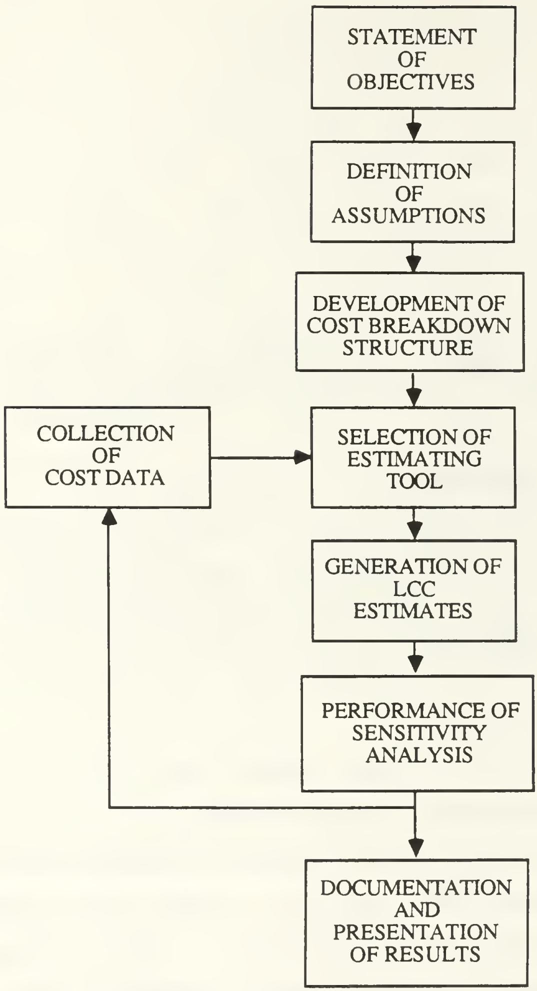

Figure 1. A Generalized Life Cycle Cost Methodology [Ref. 7:p. 22]

cycle costing and to ensure its success where presently used, this inertia must be overcome. [Ref. 10:p. 2] For success with life cycle costing methods the DOD manager:

1. Must be committed to the process. This includes making necessary resources of time and money available to the analysts for studies and estimates. [Ref. 14:p. 19]

2. Must inform and train personnel on life cycle costing procedures and goals and on how to support the effort. This will lead to decreased resistance to the life cycle costing process. [Ref. 10:p.2]

3. Must initiate the life cycle costing approach early in the acquisition process to gain the maximum benefit possible from the approach. For spare parts, the life cycle costing approach should be initiated prior to issuing the solicitation so that bidders understand the DOD's emphasis on life cycle costing. [Ref. 8:p. 24]

J. SUMMARY

This chapter provided a brief overview of life cycle costing. It presented a historical background, then discussed the objective and the importance of life cycle costing within DOD. The chapter continued by defining life cycle costs with respect to both major systems and spare parts. This is followed with a discussion of the applicability and varied uses of life cycle costing with respect to both major weapon systems and spare parts procurement. A generalized methodology was presented and finally, the requirements for the success of life cycle costing were defined. This chapter was intended to give the reader a basic overview of the concept of life cycle costing.

The next chapter will be a general discussion of spare parts procurement. It will provide a historical review of

spare parts, briefly discuss provisioning and replenishment procedures and, finally, address the major characteristics of spare parts that have been identified by researchers as important to consider when applying life cycle costing methods to spare parts procurement.

III. SPARE PARTS: A REVIEW

Spare parts are critical to the continued operational readiness of DOD's systems. Each system is composed of many parts a significant portion of which must, at some time, be reprocured to keep the system operational. [Ref. 2:p. 21]

Currently, the DOD spare parts inventory exceeds four million different types of items. Maintaining this inventory involves in excess of 15 million contract actions through 1,000 DOD contracting agencies. [Ref. 15:p. 4] These numbers give an indication of the magnitude and complexity of the spare parts procurement process.

The goal of this spare parts procurement process is to ensure that "...our military services receive timely delivery of the highest quality spare parts at lowest cost to the taxpayer". [Ref. 16:p. 9]

This chapter discusses spare parts, reviews current spare parts provisioning and replenishment procedures, and, finally, identifies spare part characteristics. Other researchers in the area of life cycle costing have identified these spare part characteristics as important to consider when applying life cycle costing techniques to spare parts.

A. A HISTORICAL PERSPECTIVE

The 1970s marked a decade of restrained military spending. This resulted in equipment, aircraft and ships being

inoperable due to a lack of spare parts. [Ref. 15:p. 3] A new administration took office in 1981 and began "...to restore defense spending and rebuild world confidence in U.S. military capability." [Ref. 15:p. 3]

In 1983, spare parts horror stories began to appear widely in the press. Suddenly, the nation became interested in spare parts procurement. In response, the Secretary of Defense, the Defense Logistics Agency, and each of the Services put in place more than 500 procurement initiatives to resolve problems uncovered during investigations of the spare parts procurement process. [Ref. 15:p. 4]

Today, DOD has much better control of the spare parts procurement process. Procurement personnel are more aware of the magnitude and importance of the process. Now, DOD is once again approaching a period of restrained military spending. To avoid recurrence of the spare parts shortages of the 1970s, DOD must better invest its procurement dollars.

B. CONSUMABLES VERSUS REPAIRABLES

There are two classes of spare parts: consumables and repairables.

1. Consumable Spare Parts

Consumables are spare parts that are disposed of when they fail or are used up. Consumables are generally less expensive than repairables. They include items such as resistors, transistors, bearings, diodes, nuts, bolts, and

screws. Some very expensive consumables also exist. An example is radar transmission tubes. [Ref. 17:p. 28]

Consumables comprise 75-80% of the spare part inventory yet they represent only 20-25% of DOD's monetary investment in spare parts. [Ref. 17:p. 29]

2. Repairable Spare Parts

Repairables, on the other hand, are spare parts that are repaired when they fail (or on a pre-arranged rework cycle) and then returned into service. [Ref. 2:p. 23] Repairables are generally more expensive than consumables. Although repairables constitute only 20-25% of DOD's spares inventory, they represent 75-80% of DOD's monetary investment in spare parts. Repairables include certain printed circuit cards, pump shafts, hydraulic pumps, valve assemblies, and avionics. These parts are repaired by maintenance personnel at the organizational, intermediate or depot level using consumables. [Ref. 17:p. 31]

Figure 2 below represents a graphic presentation of investment versus quantity of consumables and repairables.

C. PROVISIONING VERSUS REPLENISHMENT

Provisioning refers to the procedure by which initial spare parts are selected in support of a new weapon system in the initial period of its life cycle. "It is...a period of less precise forecasting and estimating." [Ref. 3:p. 21] Provisioning provides spare part support until replenishment demand patterns are established. [Ref. 3:p. 21]

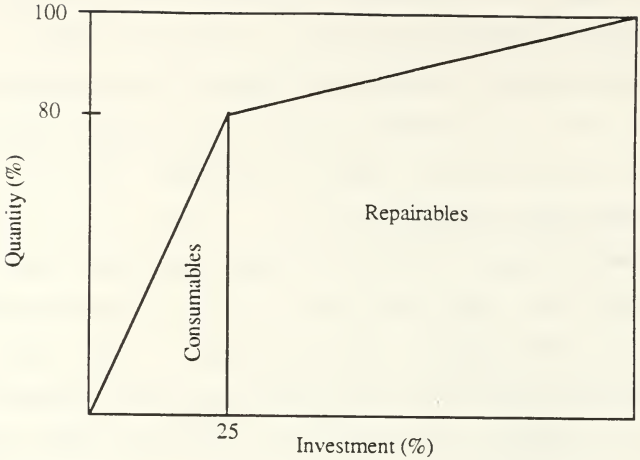

Figure 2. Total Provisioning Cost [Ref. 17:p. 30]

Replenishment refers to the process of restocking the spare parts inventory as the parts are used up through the maintenance or repair of weapon systems. Replenishment involves much more precise forecasting and estimating since it is based on actual demand history. [Ref. 3:p. 21]

D. PROVISIONING

The provisioning process is concerned with providing sufficient spare parts to support equipment delivered during a production lead time for the part, plus three months. Provisioning is limited to new spare parts which are specific to the system being procured. [Ref. 18:p. 3]

Planning for the acquisition of spare parts should begin early in the major system acquisition process. This is because design decisions made during the concept exploration

phase will affect spare parts requirements during the operation and support phase of the major system acquisition. To bring DOD's concerns regarding spare parts to the attention of contractors, spare parts criteria such as standardization, reliability or life cycle cost should be identified in solicitations, contract clauses, and should be used as selection criteria for choosing the contractor. [Ref. 3:p. 152]

In addition to the planning function for spare parts support, funding for these parts must also be considered. The programming and budgeting process must begin long before the provisioning phase of the major weapon system so that, when DOD initiates contract actions for the spare parts, the funds are available in the budget. [Ref. 3:p. 153]

When planning and funding for spare parts is completed, the actual provisioning process for the spare parts can begin. Provisioning procedures involve the complex processes of forecasting demand and estimating initial requirements. A simplified view of the provisioning process is shown in Figure 3.

Upon DOD's request, the contractor provides DOD with his provisioning recommendations. These provisioning recommendations are based on factors such as instructions from the military regarding provisioning goals, the planned maintenance concept for the weapon system, and reliability estimates for components of the system. The contractor

recommended parts list is normally submitted to DOD during the full scale development phase or early in the production phase of the weapon system's acquisition. This parts list will normally have been checked against the existing DOD inventory and should, therefore, only include new spare parts which are specific to the new weapon system and not already carried in the DOD inventory. [Ref. 3:p. 156]

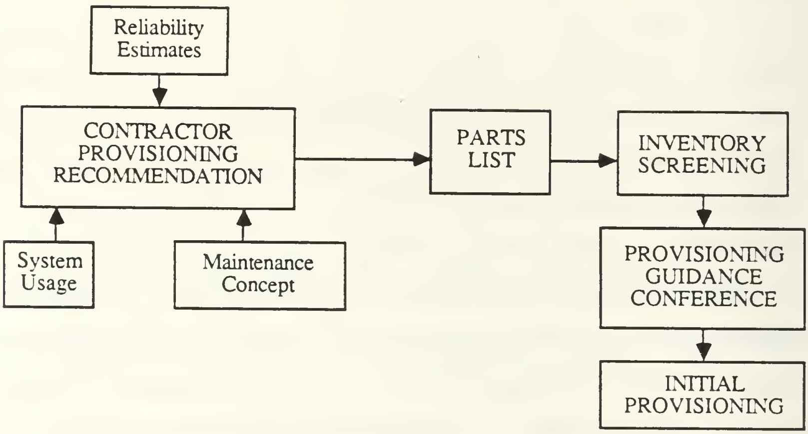

Figure 3. Simplified View of the Provisioning Process [Ref. 19:p. 28]

The next step in provisioning is the Provisioning Guidance Conference. This conference normally occurs early in the production phase of the major weapon system. This conference is basically a meeting between DOD personnel and contractor personnel to agree on the initial provisioning parts list. This conference is "...critical since it is the

base against which subsequent requirement determinations and acquisition decisions are predicated". [Ref. 3:p. 156]

Once the provisioning list has been agreed upon by DOD, modeling programs are applied to project demand during the initial provisioning period. This is the Requirements Determination Phase of the provisioning process. [Ref. 3:p. 156]

Initial provisioning usually occurs before design stabilization of the weapon system. Therefore, the list of provisioning spare parts is often subject to change. As a result, the services will usually obtain all spare parts peculiar to the new weapon system from the prime contractor of that system. This will minimize the purchase of obsolete parts because the prime contractor will be privy to all changes to the weapon system and its sub-parts. [Ref. 3:p. 157]

Once the requirements decisions have been made by DOD, provisioning orders are issued to the contractor. In response to the order, the contractor will submit a proposal on the cost of the spare parts. Negotiations between DOD and the contractor regarding the final price of these spare parts result in a contract. Finally, after award of the contract, the spares are delivered to DOD. [Ref. 3:p. 157]

E. REPLENISHMENT

Once a system is fielded, demand begins to be recorded for various spare parts. Subsequent procurement of the spare

parts is accomplished by means of the replenishment process which is based on this new demand history. Figure 4 is a simplified view of the replenishment process.

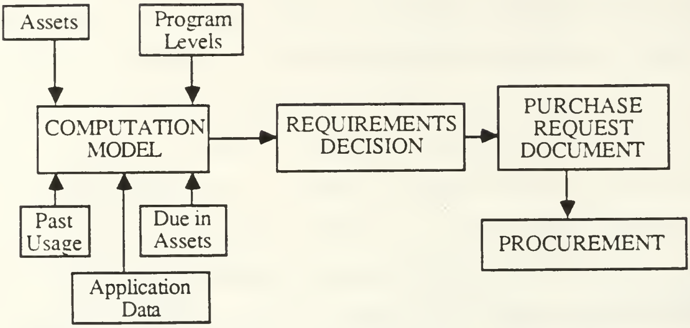

Figure 4. A Simplified View of the Replenishment Process [Ref. 3:p. 159]

To accomplish the replenishment process, all DOD activities have automated requirements computation systems which track stock levels, requisitions and procurement actions. When a shortage is detected, these systems will trigger buy notices indicating that procurement action is required. [Ref. 3:p. 159]

After buy notices are issued, requirements decisions regarding the spare parts are made. These requirements decisions are basically review actions by item managers to validate the data and make changes, as necessary. "Review actions are validated and approved at higher management levels based on the dollar value of the transaction." [Ref. 3:p. 159]

Once the review actions are completed and approvals are granted by the item manager, the buy notices result in purchase request documents. These purchase request documents are individually issued for each spare part. The purchase request documents are vehicles to obligate funds and plan and authorize procurement. [Ref. 3:p. 157]

The approved purchase request is sent to the contracting activity. At the contracting activity, contracting personnel will release solicitations for the spare part requirements, evaluate proposals received in response to the solicitation from contractors, select the winning contractor based on predefined selection criteria, and negotiate the prices of the spare parts with the selected contractor. Once negotiations are completed, the contracting officer issues a contract. Finally, the contractor delivers the spare parts as directed by the contract. [Ref. 3:p. 158]

F. SPARE PARTS CHARACTERISTICS

To apply the life cycle costing concept to the provisioning and replenishment processes of spare parts the manager must first identify candidate spare parts. To identify these candidate spare parts the manager must follow some decision process. To develop this process, the manager should consider the spare part's characteristics. An extensive literature review identified the characteristics listed on the following pages. The researcher has taken these spare part characteristics and listed them under two sub-headings:

external characteristics and internal characteristics. In Chapter IV, the characteristics considered most significant when determining whether or not to apply the life cycle costing concept to spare parts procurement are discussed. These characteristics will then be arranged in a sequence for the manager's consideration. This sequence will result in the decision model.

1. Characteristics External to the Spare Part

a. Technical Data Considerations

This characteristic refers to the necessity for or availability of technical data for reprocurement. If a spare parts is such that DOD isn't concerned with the details of its design and its function can be clearly defined, the concept of form, fit and function can be applied. [Ref. 2:p. 4]

Form, fit and function refers to an acquisition approach based on functional specifications. The functional specifications define such things as size, configuration, and performance characteristics of the spare part. Each contractor under a form, fit and function procurement has total freedom of internal design. [Ref. 20:p. 28] Detailed technical data packages are not needed for these types of procurement. A functional specification will suffice. [Ref. 2:p. 4]

If, however, the spare parts are very complex, or cannot be clearly defined in terms of function, or are

limited to a specific design (i.e., standardization requirements), then detailed technical data packages are required. [Ref. 2:p. 5] The technical data package specifies how to build the item. It details internal, as well as, external design. The result is a spare part virtually identical to the original spare part being replaced. [Ref. 20:p. 29]

b. Logistic Costs

Logistic costs are costs associated with making the spare parts available for use. Logistic costs include the cost of packaging, shipping, storing, issuing, installing, and removing the spare parts. [Ref. 2:p. 23]

c. Unit Price

Unit price refers to the cost of one spare part to DOD. It is the spare part's purchase price. [Ref. 5:p. 12]

d. Demand

Demand refers to how frequently and in what quantity the item is required. [Ref. 5:p. 4] Demand can be high or low. Demand is normally expressed in number of units per some period of time, such as a quarter of a year. The researcher believes that the following characteristics should also be considered when evaluating whether or not to apply life cycle costing methods to spare parts procurement.

e. Urgency of Requirement

This refers to how quickly the part is needed by the end user.

f. Availability of the Part on the Open Market

This refers to how readily the part can be obtained on the open market.

g. Total Cost of Procurement

This simply refers to the product of unit price times quantity ordered.

2. <u>Characteristics Internal to the Spare Part</u>

a. Performance Level

To be useful in reprocurement, the performance levels must be unambiguous objective factors based on hard historical data. Some important performance levels include the item's life, miles per gallon, and mean-time-between-failure. [Ref. 5:p. 9]

b. Performance Measure

The term performance measure refers to how the level of performance is defined and measured. [Ref. 2:p. 40] The reader must understand that some parts may have no effective performance measure (e.g., an electrical fuze). The following are examples of types of measures:

(1) <u>Work Output per Energy Input</u>. An example of this performance measure is miles per gallon.

(2) <u>Mean-Time-to-Failure or Mean-Time-Between Failure</u>. This measure applies to consumables and repairabl-es, respectively, and is a common measure of reliability. Examples of this measure are days to failure and number of flight hours to failure.

(3) Work Output to Failure. An example of this measure is the number of charge-discharge cycles on a battery after which it must be replaced.

(4) Maintainability. This performance measure is frequently measured in terms of mean-time-to-repair. Maintainability refers to the ease with which a repairable can be restored to a given condition or the ease with which a consumable item can be replaced. [Ref. 13:p. 79]

These four categories of measures aren't the only appropriate measures of performance. Users of the end item and engineering personnel should be able to identify other measures for the item manager.

c. Durability/Reliability

Durability/Reliability refers to the effective lifetime of the spare part. It is the probability that an item will perform over some period of time under given conditions. [Ref. 13:p. 80]

d. Inherent Availability.

Inherent availability refers to the maximum availability possible with the given design. Availability, in this context, means the proportion of time that the item is able to perform its function. This characteristic does not apply to consumables. [Ref. 13:p. 79]

Although the following characteristics were not specifically mentioned in the literature reviewed, the

researcher considers the following characteristics to be significant.

e. Shelf Life

Shelf life refers to the length of time that the item may remain in storage. A shelf life of six months means that the item must be used within six months of being produced. Not all spare parts have a shelf life.

f. Maturity

Maturity refers to how well developed the design of the spare part is. The spare part's design can be mature, that is fully or highly developed, or it can be state-of-the-art.

G. SUMMARY

This chapter discussed spare parts. The provisioning and replenishment processes for spare parts were briefly discussed and several spare parts characteristics were identified. In the following chapter the decision model to assist managers in determining the applicability of life cycle costing to spare parts procurement is developed.

IV. THE DECISION MODEL

Chapter III reviewed DOD's present spare parts procurement processes and identified characteristics of spare parts which should be considered when contemplating the use of life cycle concepts in the spare part's procurement. In this chapter, the researcher will choose, from the characteristics identified in Chapter III, those characteristics which are most important to consider when evaluating the applicability of life cycle costing methods to spare parts procurement. These characteristics will then be arranged into the most effective order for consideration in the decision model.

A. OBJECTIVE OF LIFE CYCLE COSTING OF SPARE PARTS

At this point, the researcher would like to re-emphasize the purpose of applying the life cycle costing concept to spare parts procurement.

> LCC is not and should not become the technique or tool for overcoming engineering or purchasing problems. LCC is only a basic and definitive procurement tool to select some offerers or approaches in a manner that achieves minimum cost per unit of utility. [Ref. 2:p. 39]

In developing the decision model for identifying spare parts to which the life cycle costing concept should be applied, this ultimate objective of obtaining spare parts at the lowest cost per level of performance should be kept in mind.

B. CHARACTERISTICS SIGNIFICANT TO LIFE CYCLE COSTING

In conducting the literature review, the researcher encountered several of the spare part characteristics identified in Chapter III more frequently than others when spare parts were addressed in relation to life cycle costing. The characteristics most frequently referred to were: technical data, unit price, demand, performance level, the chosen performance measure, and durability. This researcher believes that the following characteristics are also important to consider: urgency of the requirement, availability on the open market, shelf life, maturity, and total procurement cost.

C. ORDER OF CONSIDERATION OF CHARACTERISTICS

The researcher has determined that the most effective order of consideration for the chosen spare part characteristics is from that characteristic most clearly defined and easiest to identify to that characteristic most difficult to define and identify. In following a decision process, it is more reasonable to use the characteristic that is simplest to identify first so that a decision maker can easily disqualify spare parts inappropriate for the application of the life cycle costing concept. As the user of the life cycle costing decision model proceeds through the model, the characteristics become harder to quantify, but the user will be studying fewer candidate items. So his overall workload will be reduced.

Consider, on the other hand, applying the spare part characteristics in the reverse order. A user would need to define and identify complex characteristics for all parts to be considered for application. This will be very labor intensive, costly and inefficient. Many of the parts that would have been researched in depth to define complex characteristics such as durability and current utility levels, will be eliminated. It will be much more efficient to eliminate as many parts as possible from consideration using obvious characteristics such as need, shelf life and procurement cost.

The researcher has identified the following order of consideration for the chosen spare part characteristics:

1. Urgency of requirement
2. Shelf life constraints
3. Availability on the open market
4. Maturity
5. Total procurement cost
6. Demand
7. Unit price
8. Durability/Reliability
9. Technical data considerations
10. Performance measures
11. Performance level

Each of these characteristics and their order of consideration will be discussed in detail in this chapter.

D. THE DECISION MODEL

Figure 5 is a flowchart of the decision model to be used for identifying spare parts that are candidates for the application of the life cycle costing concept. It is designed to provide the model user a simple process to identify spare part candidates for procurement using life cycle costing methods. Its purpose is to eliminate spare parts not appropriate for the application of life cycle costing methods. For those spare parts that successfully complete all steps of the decision model, the decision model then leads the model user to define the current cost per unit of utility. Finally, to provide the contracting personnel with a life cycle cost selection criteria, the model user determines the cost per unit of utility that is desired for the part.

The outputs of the model are (1) those spare parts that will lend themselves to life cycle costing methods and (2) the cost per unit of utility that the manager wishes to attain for the spare parts under consideration.

E. URGENCY OF REQUIREMENT

The first step in the model is concerned with the time frame in which the spare part is needed. The researcher estimates that the process of applying the Graham Decision Model for Spare Parts, gathering data on factors such as technical data and performance levels, obtaining engineering estimates on utility levels, and proceeding through the

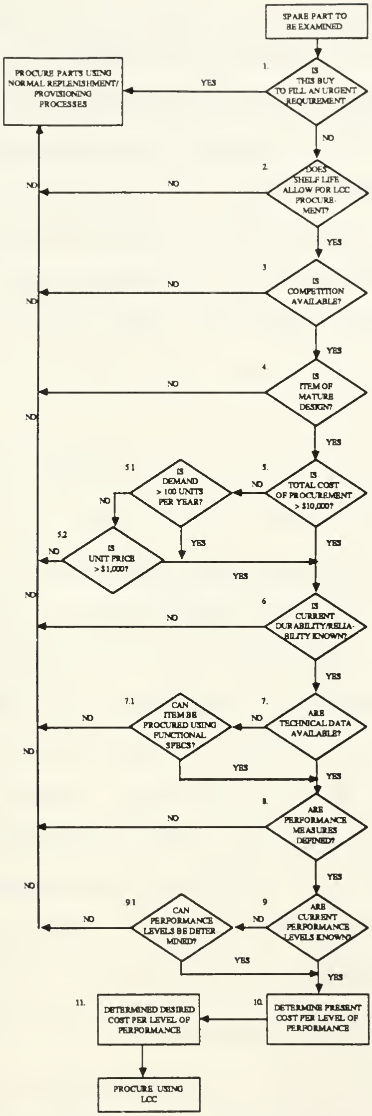

Figure 5. The Graham Decision Model for Spare Parts

contracting process (i.e., solicitation, proposal, negotiation, award, and delivery) will require a minimum of six months. Therefore, to use the life cycle costing process, the user must have at least six months available. As a result, this process will not lend itself to urgent requirements. Urgent requirements should be filled using normal replenishment processes. If, however, the required time of six months or more is available, then the user should proceed to step two.

F. SHELF LIFE

Step two involves looking at the spare part's shelf life. If the items shelf life is very short (i.e., six months or less), then, unless the shelf life can be improved, life cycle procurement will be inappropriate for use. The user of this model should consider the possibility of using life cycle costing methods to increase the shelf life. In effect, this would amount to buying a longer shelf life per dollar. If the shelf life of the spare part exceeds six months, if the spare part does not have a defined shelf life, or if the spare part's shelf life could be improved using life cycle costing methods, then the user should continue to step three. Otherwise, use standard procedures.

G. AVAILABILITY ON THE OPEN MARKET

Step three deals with the availability of competition. The researcher believes that, to make life cycle costing

techniques effective, competition is essential. Competition will provide contractors with the incentive to meet and exceed minimum criteria at the lowest cost possible. This is not to say that life cycle costing isn't possible with sole source contractors, but the researcher expects that the costs to DOD of minimizing the cost per unit of utility would be exorbitant. Experience has shown that in a non-competitive environment, DOD has paid much higher prices for spare parts. Therefore, if the spare part can be obtained from more than one source, continue to step four. Otherwise, use normal procurement procedures.

H. MATURITY

Step four is concerned with whether the spare part is of mature design or state-of-the-art. The researcher contends that a state-of-the-art item will tend to be too complex for life cycle costing techniques. State-of-the-art spare parts tend to have insufficient historical data available on them to determine actual durability or performance levels and engineering estimates of durability and performance levels will contain substantial error. As a result, the user should stick to spare parts of mature design. If the part is considered to be mature, then proceed on to step five. Otherwise, buy spare parts using standard procedures.

I. TOTAL COST decision #5

Step five is comprised of two sub-parts: unit price and demand. Total cost is significant because, as stated in Chapter II, the spare part procurement must be large enough, in terms of dollar value, so that a marginal improvement in life cycle cost will be greater than the added cost of administering the life cycle procurement. [Ref. 5:p. 4] The total procurement cost cut-off chosen by the researcher is $10,000 which is compatible with Reinhardt's criterion. The dollar value was arbitrarily chosen and may require adjustment once DOD gains experience with life cycle procurement of spare parts. If the procurement meets this floor, regardless of the unit price and the quantity demanded, then the user should proceed to step six.

However, if the procurement does not meet the total cost criterion of $10,000, then the user must examine the demand and unit price.

1. Demand

The researcher believes that before totally rejecting a spare part based on the total cost criterion, the demand for the item must be considered. Demand refers to how frequently and in what quantity an item is required. The researcher has set this criterion at demand greater than 100 units per year. This value is considered large enough to make the additional administrative burden incurred as a result of applying life cycle costing methods worthwhile.

The value was arbitrarily chosen and may require adjustment once actual cost data are available. If the spare part meets this sub-criterion, then continue to step six. Otherwise, test the unit price.

2. Unit Price

One more test is required before disqualifying the spare part as a candidate for life cycle costing methods: the unit price test. To override the rejection of the spare part by the model thus far, the spare part's unit price must be greater than $1,000. The researcher has chosen this value because it appears high enough to allow for small improvements in life cycle cost to be greater than the increased administrative costs of the spare part procurement. This unit price threshold cannot be tested until cost and savings data are available on actual life cycle cost procurement. This value may, therefore, require adjustment.

If the rejected spare part meets this criterion, then the user should continue on to step six. Otherwise, procure the spare part using normal replenishment procedures.

J. DURABILITY/RELIABILITY decision #6

The test for durability/reliability occurs in step six. Durability refers to the effective lifetime of the spare part. To continue with this model, the user must know what the "effective lifetime" is. The effective life may be defined in the specifications for the part in question, or

may be available in maintenance records, or can be determined by engineering personnel.

If the durability of the part cannot be determined, then the spare part should be procured using standard provisioning or replenishment methods. If, however, the effective lifetime can be defined, then proceed on to step seven.

g K. TECHNICAL DATA (7)

Step seven is concerned with the availability or necessity of technical data. Technical data are normally required for the re-procurement of spare parts. The first concern regarding technical data is whether or not technical data are available. If the data are available, then the user of The Graham Decision Model for Spare Parts can proceed to step eight.

If, however, technical data are not available, then the model's user should determine if functional specifications are available or can be determined. If functional specifications are available and the end user of the spare part is not concerned with the detailed design of the part, then the user of the model can proceed to step eight. Otherwise, the user should procure the parts using normal procurement methods.

h. L. PERFORMANCE MEASURES (8)

Step eight simply involves determining if performance measures are defined. If they are not defined, then the user should investigate if they can be determined by engineering

personnel. If performance measures are not available and cannot be determined, then the user of this model should procure the parts using standard procurement methods. If, on the other hand, performance measures such as charge-discharge cycles, flight hours, miles per hour, or mean-time-to-failure are identified, then the user should proceed to step nine. The reader must be aware that some spare parts may have more than one applicable performance measure. It is then up to the item manager, with help from engineering personnel, to decide which performance measure to use in the procurement using life cycle costing methods.

M. PERFORMANCE LEVELS 9

Step nine is the final step in determining the applicability of life cycle costing to the spare part's procurement. For the spare part that has successfully completed all steps of the Graham model, the user should now determine the current levels of performance. Current performance levels would be expressed in terms such as 3000 flight hours, 35 miles per gallon, and 10 charge-discharge cycles. Determining the current performance level is important because, to apply life cycle costing methods to minimize the cost per level of performance, the user must know what the current level is, so that higher levels can be set as a goal for future procurements. If the current level of performance is known, then the spare part is a candidate for the application

of life cycle costing techniques. The user should proceed to the next step.

If the current level is not known, then the user can review maintenance records and use engineering talents to determine the current level of performance. If the level cannot be determined or estimated, then the user should procure the part using standard methods. If, however, the level of performance can be estimated, then the spare part is a candidate for the application of life cycle costing methods. The user should proceed to step ten.

N. COST PER LEVEL OF PERFORMANCE

By step ten, the spare part has successfully passed the tests of the Graham decision model and is a candidate for procurement using life cycle costing techniques. At this step in the model, the user should determine current cost per level of performance. The cost per level of performance is determined by dividing the unit cost of the spare part by the performance level. For example, if a spare part costs $1000 and its current performance level is 3000 flight hours, then the spare parts cost per level of performance is $.33 per flight hour. Next, the user will determine the desired cost per level of performance for the procurement using life cycle concepts.

O. DESIRED COST PER LEVEL OF PERFORMANCE

This is the final step of this model. Knowing the current cost per unit of performance, the user, with the aid of engineering personnel, can determine the desired cost per level of performance. In the example presented in subparagraph N above, engineering personnel may determine that \$.25 per flight hour is the desired cost acceptable to DOD. On the other hand, \$.33 per flight hour may be a very reasonable value and DOD wants to keep costs at this level. In either case, the criterion that DOD will want a contractor to meet will have to be defined so that contracting personnel will understand the end user's requirements. This cost criterion will be identified in the solicitation document provided to prospective contractors and will be one of the selection criterion for selecting the successful offeror. Note: For clarity sake, the solicitation must clearly state whether the cost criterion is a maximum or simply a goal and it must define the acceptable standard deviation.

P. SUMMARY

This chapter took the spare part's characteristics identified in Chapter III, ordered them into a sequence for consideration and then built a decision model using these characteristics. The purpose of this chapter was to provide the manager with a tool to select viable candidates for the application of life cycle costing methodologies to spare parts procurement. This was accomplished with the develop-

ment of the Graham Decision Model for Spare Parts. The next chapter will demonstrate the use of this model using two spare parts.

V. DEMONSTRATION OF THE MODEL

Chapter IV developed a decision model for determining the applicability of life cycle costing to spare parts procurement. This chapter will demonstrate the model using two aviation parts: a catapult hold back fitting assembly and an arresting gear hook shank. These parts were chosen because within the last six months they had undergone a should cost analysis. Therefore, the information needed to properly apply the Graham Decision Model for Spare Parts was readily available.

A. THE SPARE PARTS

1. Catapult Hold Back Fitting Assembly

This fitting is a standard stock part (a part normally carried within the Navy supply system) with a national stock number of 1560-00-421-8542. Technical data for the part are available and are sufficient to allow competition. The part is an assembly composed of a holdback, fingers and pin. "Although all components are interchangeable, squadron personnel try to keep components as a matched set. This allows for less assembly and disassembly cycles for required inspection intervals." [Ref. 21] The assembly has an effective life of 750 catapult shots and must be inspected at the IMA level after every 100 catapult shots. [Ref. 21]

2. Arresting Gear Hook Shank

The hook shank is also a standard part. Its national stock number is 1560-00-127-0242. Technical data are available and considered adequate for competition. The effective life of this part is 1000 arrestments and requires IMA level inspection every 125 arrestments. [Ref. 21]

B. APPLICATION OF THE MODEL

The following is a step by step demonstration of the model:

Graham Decision Model Steps:	Catapult Hold Back Fitting Assembly:	Arresting Gear Hook Shank:
Step 1: Is the buy to fill an urgent requirement?	No	No
Step 2: Does shelf life allow for life cycle cost procurement?	Yes. The part does not have a shelf life, therefore, this step is actually not applicable.	Yes
Step 3: Is competition available?	Yes	Yes
Step 4: Is item of mature design?	Yes. Drawings are dated August 1977.	Yes. Drawings are dated August 1983.
Step 5: Is total cost of procurement > $10,000?	No. Total procurement costs average about $2,632.	Yes. Total procurement costs is about $14,403.
Step 5.1: Is demand > 100 units per year?	Yes. Average demand is approximately 230 assemblies per year.	N/A (Not applicable)

Step 5.2: Is unit price > $1,000?	N/A	N/A
Step 6: Is current durability/reliability known?	Yes, 750 catapult shots.	Yes. 1000 arrestments.
Step 7: Are technical data available?	Yes	Yes
Step 7.1: Can item be procured using functional specifications?	N/A	N/A
Step 8: Are performance measures defined?	Yes, number of catapult shots.	Yes, number of arrestments.
Step 9: Are current performance levels known?	Yes, the researcher will use the effective life (750 catapult shots) as the current level of performance.	Yes, the researcher will use the effective life (1000 arrestments) as the current level of performance.
Step 9.1: Can performance levels be determined?	N/A	N/A
Step 10: Determine present cost per level of performance.	Current cost per level of performance is determined by dividing the unit price ($28.30) by the level of performance (750 catapult shots). Current cost per level of performance is $.04 per catapult shot.	Unit cost ($87.29) divided by the level of performance (1000 arrestments) is $.09 per arrestment

Step 11: Determine desired cost per level of performance.	Based on a should cost study, $.04 per catapult shot is a reasonable cost per level of performance. This value is, therefore, the goal of this procurement.	Based on a should cost study, $.09 per catapult shot is a reasonable cost per level of performance. This value is, therefore, the goal of this procurement.

C. THE END RESULT

Both of the spare parts are candidates for procurement using life cycle costing methods. Within DOD, life cycle costing techniques have not been applied to spare parts other than items such as batteries and aircraft tires. Nonetheless, the item manager could now prepare a purchase request for the life cycle procurement of the catapult hold back fitting assembly and the arresting gear hook shank.

The purchase request would identify the cost criterion to be met by offerors (e.g., $.04 per catapult shot or $.09 per arrestment). After the proper approvals (as required by local operating procedures), this purchase request would then be submitted to the purchasing department.

The procurement would progress as normal except for the additional cost criterion in the solicitation document. The procurement personnel may need to hold discussions with prospective offerors to clarify DOD's requirement, but once the requirements are understood, proposals could be submitted by contractors.

The evaluation and source selection process will involve standard procedures except that, instead of evaluating the proposals on the basis of lowest purchase price, the proposals would be evaluated on the basis of cost per level of performance.

D. SUMMARY

This chapter demonstrated the Graham Decision Model for Spare Parts. The following chapter discusses findings and recommendations.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The purpose of this thesis is to develop a qualitative decision model to be used as a tool by DOD's item managers. The model will assist the manager in determining if a spare part is a candidate for the application of life cycle costing techniques to the spare part's procurement.

To develop this decision model, the researcher reviewed the life cycle costing concept as it is applied to major weapon systems. The researcher also reviewed present spare part provisioning and replenishment procedures. The final step towards developing the qualitative decision model was the identification of spare part characteristics. The characteristics identified were those considered important when attempting to identify spare parts that are candidates for life cycle costing techniques. The product of this work is found in Chapter IV.

B. CONCLUSIONS

1. <u>Very few studies have been completed in the area of spare parts procurement using life cycle costing techniques</u>.

The literature review yielded only one study performed specifically on the application of life cycle costing techniques to spare parts procurement. Written by Markowitz in 1971, it is entitled <u>Life Cycle Costing Applied to the</u>

Procurement of Aircraft Spare Parts. Another study was done by Reinhardt and Leggett in 1977 and, although its purpose was not to specifically address life cycle costing for spare parts, it did briefly discuss life cycle costing for consumables such as aircraft tires and batteries. This latter study was entitled The State of the Art of Life Cycle Costing.

2. Life cycle costing techniques are not currently applied to spare parts procurement within DOD.

As shown in Chapter III of this thesis, provisioning and replenishment processes do not currently include a step for considering the application of life cycle costing techniques to the procurement of DOD spare parts. Although this thesis provides a qualitative model for identifying spare parts that are candidates for procurement using life cycle costing methods, there are no quantitative life cycle costing models for spare parts for estimating what the total life cycle cost of the spare part is or should be.

3. The Graham Decision Model for Spare Parts will identify spare parts that are candidates for procurement using life cycle costing methods.

The Graham Decision Model for Spare Parts is a tool to be used by item managers and contracting personnel for identifying spare part candidates for procurement using life cycle costing techniques. It uses the particular spare part's characteristics to determine its candidacy, therefore, it can

be used for evaluating any spare part within the DOD inventory.

4. <u>Certain spare part characteristics are susceptible to life cycle costing methods</u>.

The characteristics that are susceptible to life cycle costing methods are: urgency of need, shelf life constraints, availability on the open market, maturity, total procurement cost, demand, unit price, durability, technical data considerations, performance measures, and performance level.

5. <u>Certain spare parts lend themselves to procurement using life cycle costing techniques</u>.

The Graham Decision Model for Spare Parts will identify those spare parts that do lend themselves to procurement using life cycle costing techniques. This thesis addressed one of the possible ways to measure the effectiveness of life cycle costing methods. That measure was defined by Reinhardt and was expressed in terms of cost per unit of utility. The reasoning in measuring the effectiveness of life cycle costing methods in terms of cost per unit of utility was that the lower the cost per unit of utility, the lower the total life cycle cost for the item will be. So, for those spare parts for which the manager can define the effective lifetime, the level of performance, and for which the unit cost is known, the current life cycle cost can be determined and new life cycle cost goals can be set for future procurements.

C. RECOMMENDATIONS

1. <u>Conduct an up-to-date study on applying life cycle costing techniques to the procurement of spare parts</u>.

After an extensive search, only one study specifically addressing life cycle costing and the procurement of spare parts was found. That study was the Markowitz thesis, <u>Life Cycle Costing Applied to the Procurement of Aircraft Spare Parts</u> (1971). Since 1971, DOD has gained a great deal of experience with the life cycle costing of major weapon systems. The experience gained and the lessons learned from applying life cycle costing methods to major weapon systems over the past 17 years may have significant impact on the application of life cycle costing techniques to spare parts procurement.

2. <u>Apply life cycle costing techniques to the procurement of spare parts identified as candidates for the process</u>.

For spare parts identified as candidates for procurement using life cycle costing techniques by the Graham Decision Model for Spare Parts, use the cost per unit of performance as a means to improve on the life cycle cost of the spare part. To accomplish this:

- The solicitation for the spare part procurement must identify the cost per unit of utility measure.
- The contractors must be educated on the DOD concern for the life cycle cost of the spare part.
- The life cycle cost criterion should be made a major source selection criterion.

D. ANSWERS TO THE SUBSIDIARY RESEARCH QUESTIONS

1. What are life cycle costs?

Life cycle cost is the total cost of the research & development, investment, operation & support, and disposal of a weapon system.

2. How are life cycle costing methods applied to major system acquisition?

On a major weapon system, life cycle costing methods are applied as early as possible in the acquisition cycle. As detailed in Chapter II, to apply life cycle costing methods the manager must identify the objective of the life cycle cost procurement, define assumptions regarding unknown factors such as future interest rates, develop a cost breakdown structure for major elements of the system, the system components and the functional activity areas, select an estimation tool, collect data, generate the life cycle cost estimates, perform sensitivity analysis on the estimates, and, finally, document the analysis.

3. What are spare parts?

Spare parts are spares and repair parts purchased for use in the maintenance, overhaul and repair of equipment.

4. What are the principal characteristics of spare parts?

The principal characteristics of spare parts when considering the application of life cycle costing techniques to the procurement of spare parts are the availability of

technical data for reprocurement, logistic costs, demand, unit price, urgency of requirement, availability on the open market, utility level, performance measure, durability, reliability, maintainability, inherent availability, shelf life, and maturity.

5. What spare part characteristics are significant to determining the applicability of life cycle costing methods to spare part procurement and how should these be considered in determining the applicability of life cycle costing?

The characteristics that are significant to determining the applicability of life cycle costing methods to spare part procurement and the order of their consideration are as follows: time available for procurement, shelf life constraints, availability on the open market, maturity, total procurement cost, demand, unit price, durability, technical data considerations, performance measures, and utility level.

6. What are the key elements of a decision model which could be used to identify candidate spare parts for life cycle costing and how should the model be applied?

The key elements of the decision model are the characteristics identified in response to question five above. The model requires that the user of the model evaluate each spare part against each of the characteristics identified as significant. Any spare part meeting all the criteria of the model is a candidate for the application of life cycle costing to its procurement.

E. ANSWER TO THE PRINCIPAL RESEARCH QUESTION

What decision process should be used to determine application of life cycle costing to spare parts?

The answer to this question is found in Chapter IV. The Graham Decision Model for Spare Parts is the decision process that should be used to determine the application of life cycle costing to spare part procurement. The user of the model will evaluate each spare part against the first nine steps of the Graham model. If the spare part meets all of the criteria of the first nine steps, then the spare part is a candidate for procurement using life cycle costing methods.

F. RECOMMENDATIONS FOR FURTHER STUDY

1. A study on the application of life cycle costing methods to the procurement of spare parts.

The most recent study in the area of applying life cycle costing techniques to the procurement of spare parts was performed by Markowitz in 1971. An updated study is needed to incorporate current life cycle costing policies, procedures and lessons learned to the application of life cycle costing techniques to the procurement of spare parts.

2. Develop a quantitative life cycle costing model for spare parts.

This study may involve developing an entire life cycle costing model designed specifically for spare parts or adapting a life cycle costing model designed for major weapon systems to the spare parts procurement process. The measure

of the effectiveness of life cycle costing techniques for spare parts was identified in this thesis as cost per unit of utility. A quantitative life cycle cost model would also consider costs such as storage costs, maintenance costs and costs of failure of the spare part.

3. <u>Perform a cost benefit analysis on the cost effectiveness of applying life cycle costing techniques to the procurement of spare parts</u>.

The cost benefit analysis would determine the costs as well as the benefits of applying life cycle costing techniques to the procurement of spare parts. The cost and benefits would then be compared to determine if the benefits gained by applying life cycle costing methods to the procurement of spare parts exceed the costs of administering the procurement.

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